Fundamentals of embedding antennas

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Abstract

This paper shows the importance of observe the complete product when embedding antennas. It is shown that metal objects, such as the PCB onto the antenna is mounted, influence the antenna resonance frequency and radiation characteristics. Measurements of both resonance frequency and radiation characteristic are important to ensure that the wireless unit will function as expected. Since the radiation properties also are set by other objects than the antenna, it needs to be taken into account when developing a new product. The resonance frequency and radiation properties will vary depending of the size and shape of the PCB which the antenna is mounted onto. This paper also shows the importance of taking care of EMC issues when developing the product. Very small noise levels will decrease the receiver sensitivity for the receiver. It is important to verify that no such noise occurs.

1. Introduction

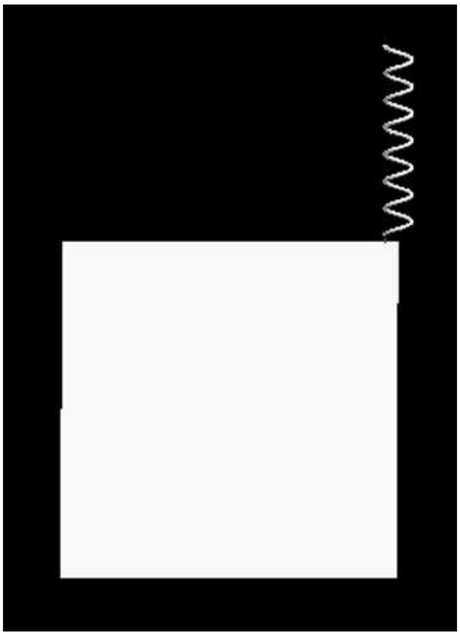
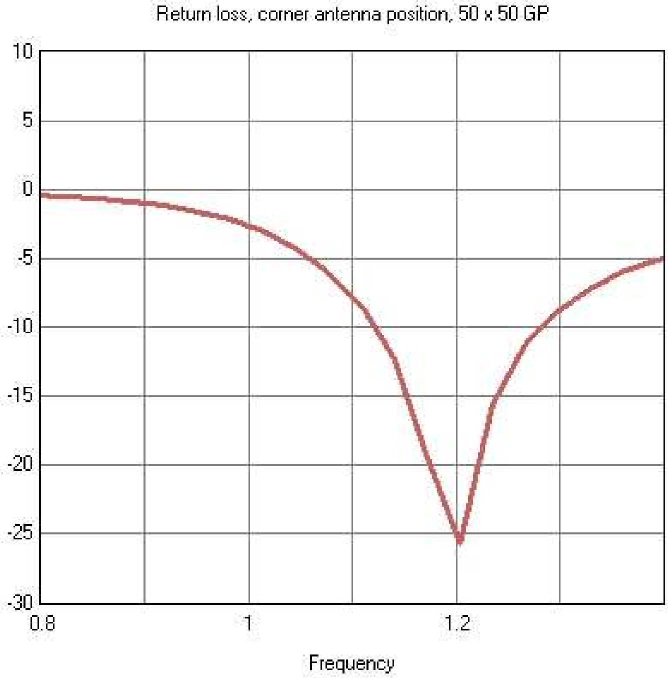
The trend in wireless devices, started by Nokia and their handsets, is to embed the antenna into products instead of having external stub antennas. This is attractive to create well designed products that appeal the customers. For engineers the embedding of antennas creates new challenges. For the antenna engineer the toughest task is to achieve a small antenna that both radiates well and have a good impedance match despite it is located close to other objects. For GSM systems bandwidth requirements and usage of multiple frequency bands increase antenna development complexity. The RF-receiving circuit is also very sensitive and will attract noise and spurious from the digital electronics into the radio receiver so the PCB layouts are very important.

All antennas in embedded applications are resonant antennas. This mean that the antenna needs to create radiating structure that is a half of a wave length. The antenna placed in the product and the radiating structure usually isn't the same. The antenna is only a part of the radiating structure. The radiating structure includes also other metallic objects close to the antenna and also the PCB that the antenna is connected to. A quarter wave antenna needs other metallic object to create a half wave structure for radiation. A dual band antenna needs two half wave structures for radiation at the two frequencies. The aim with this paper is to show the importance to measure the antenna characteristics when mounted on the product and to optimize the performance to get a good product.

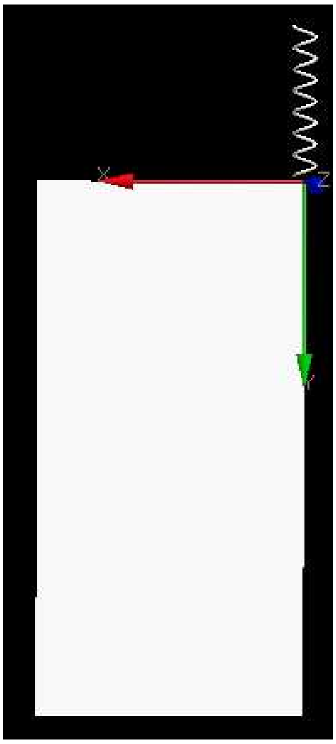
2. Antenna characteristics dependent of Ground plane and position

This paper focus in showing the basic difference in performance when placing the same helical antenna to PCB's with different sizes and placing the antenna at different position. The results are simulated in XFDTD and give a rough view of how the PCB size and position of antenna affect the resonance frequency, radiation pattern and antenna impedance. No tuning or optimizations is performed since the aim is to visualize the need for antenna optimization of standard antennas when used in embedded applications. Table 1 show the different set-ups and its corresponding return loss diagram, table 2 visualize the electric field at resonance frequency and table 3 shows the radiation pattern of three different set-ups. The difference in resonance frequency and the radiation pattern between the different set-ups is significant.

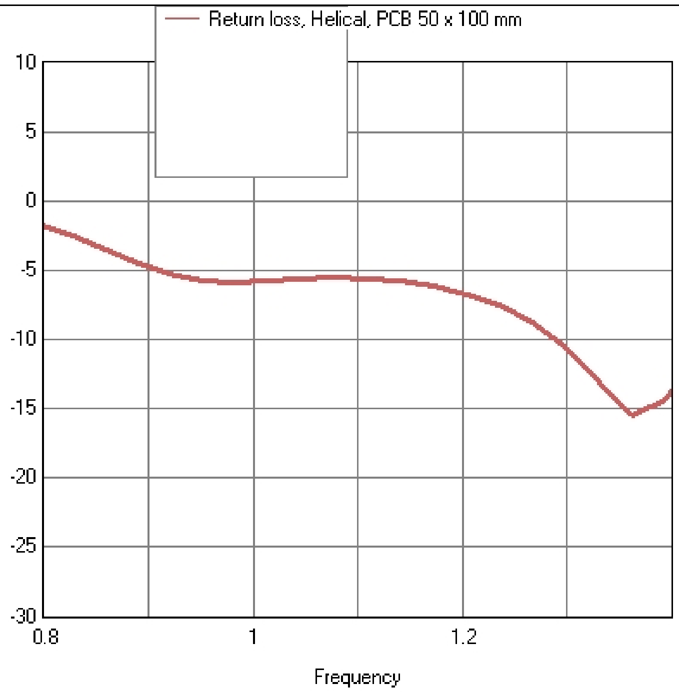
Table 1: VSWR result from one antenna placed on different PCB's

SET-UP 1  Antenna on 50 x 50 mm Ground plane.	 Return loss for antenna on 50 x 50 mm Ground plane.

SET-UP 2



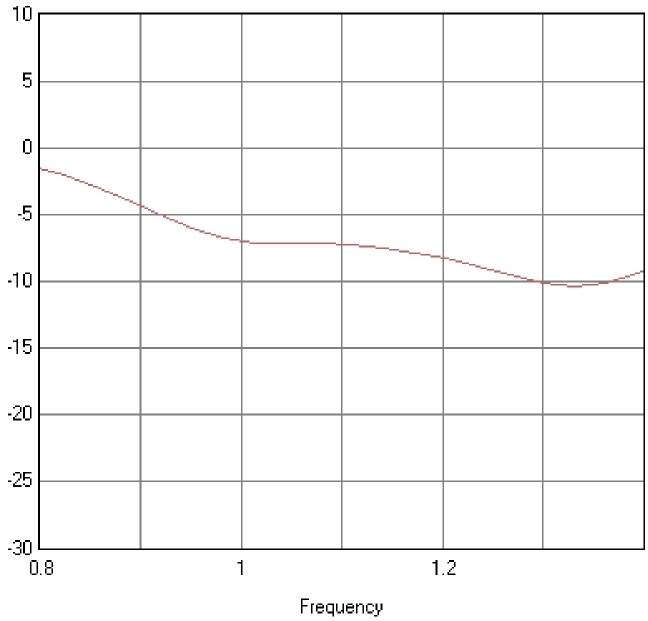
Antenna on 50 x 100 mm Ground plane.



The SET-UP 2 gives two different resonance frequencies. This is due to the rectangular shape of PCB and antenna position on the PCB. Two different modes of half wave structure is possible. One giving a resonance frequency at 1.0 GHz and the other at 1.35 GHz.

SET-UP 3

Antenna on 100 x 50 mm Ground plane.



The SET-UP 3 gives two different resonance frequencies. This is due to the rectangular shape of PCB and antenna position on the PCB. Two different modes of half wave structure is possible. One giving a resonance frequency at 1.0 GHz and the other at 1.32 GHz.

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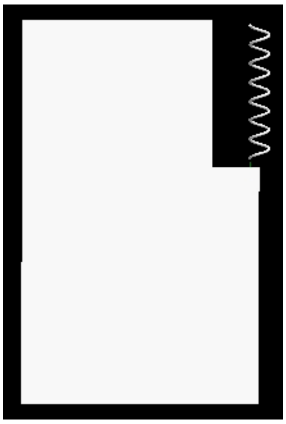
SET-UP 4



Antenna on 80 x 50 mm ground plane with antenna located close to Ground plane.

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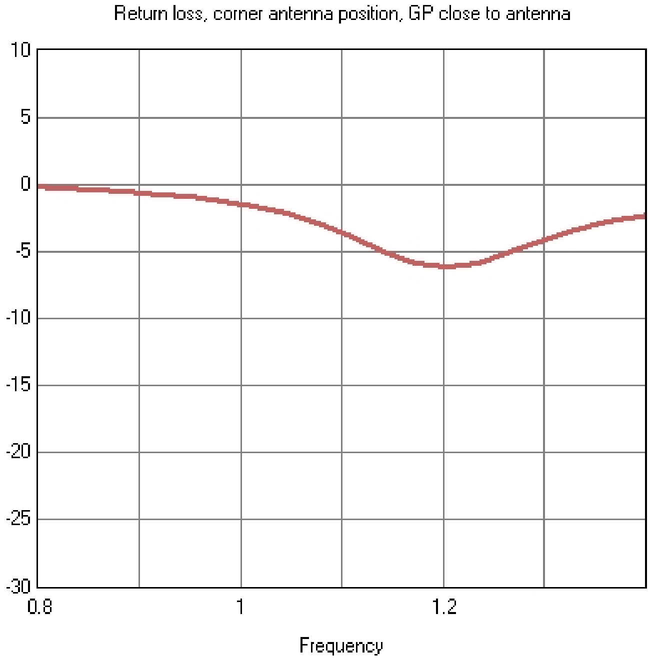

The SET-UP 4 gives the same resonance frequency as SET-UP 1 but having less good impedance match to 50 ohms compared to the SET-UP 1. This is caused due the fact that the antenna is closer to the Ground plane. Impedance match is needed to improve the return loss.

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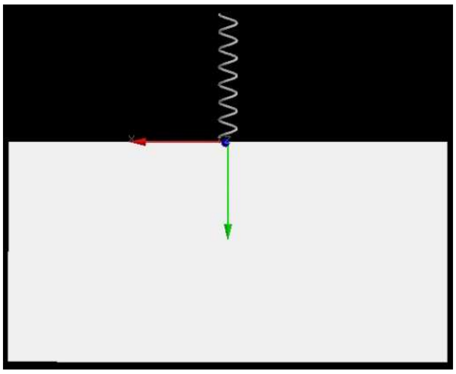
SET-UP 5



Antenna on 100 x 50 mm Ground plane with antenna located at center position.

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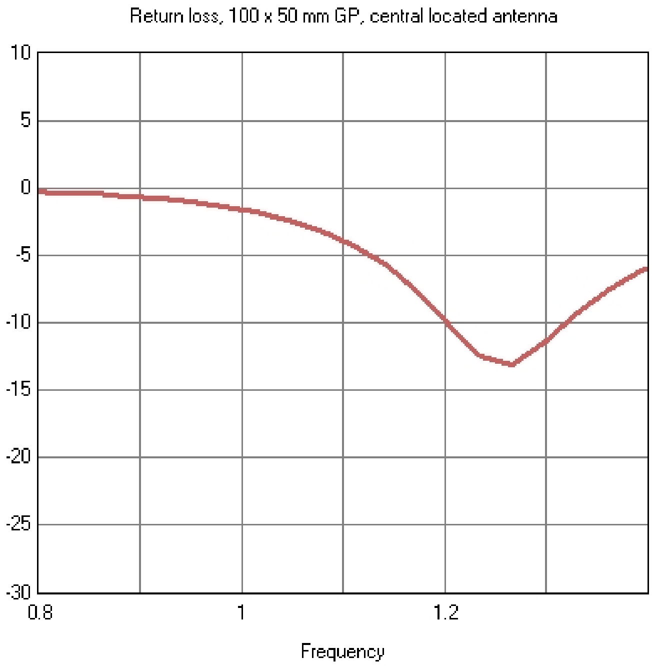

This PCB is the same as SET_UP 3 but the antenna is located at a center position having the same distance to the lower end corner of PCB as the SET-UP 1. This move of antenna changes the resonance frequency so it looks like the SET-UP 1.

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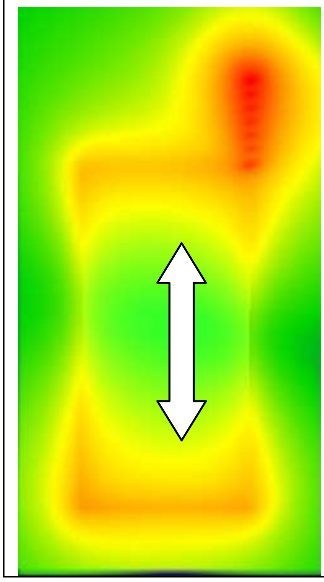
Table 2: Electrical field of one antenna placed on different PCB's

SET-UP 1:

Electric field over the antenna and PCB Ground plane at the resonant frequency of 1.2 GHz. Arrows show the main direction of electromagnetic field over the PCB.

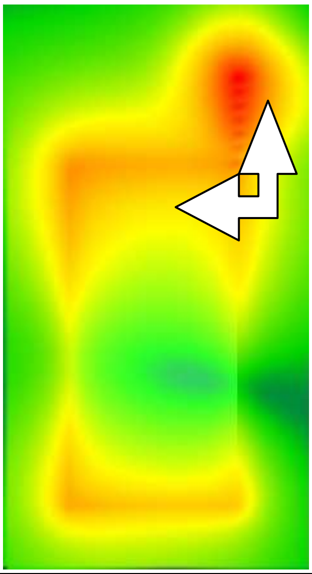
SET-UP 2:

Electric field over the antenna and PCB Ground plane at the resonant frequency of 1.0 GHz. Arrows show the main direction of electromagnetic field over the PCB. This gives a longer length than the SET-UP 2 and therefore lower resonance frequency.



SET-UP 2:

Electric field over the antenna and PCB Ground plane at the resonant frequency of 1.35 GHz. Arrows show the main direction of electromagnetic field over the PCB. This gives a shorter length than the SET-UP 2 and therefore higher resonance frequency.



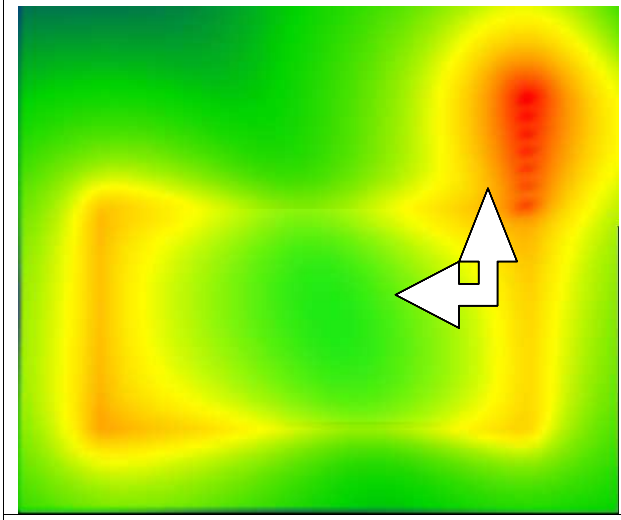
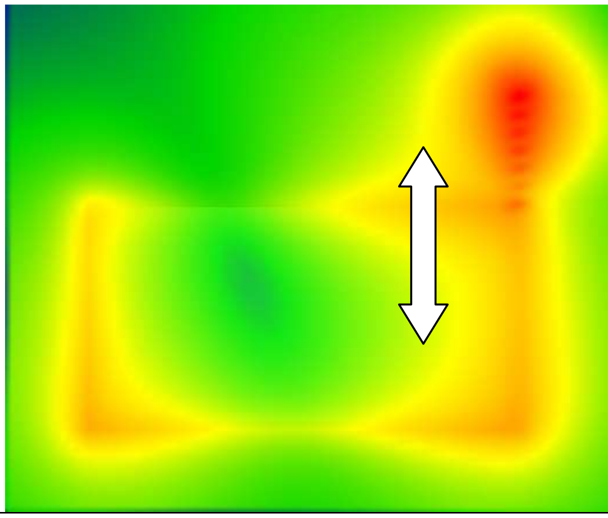
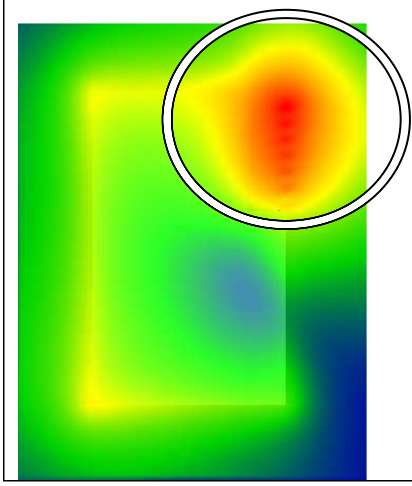
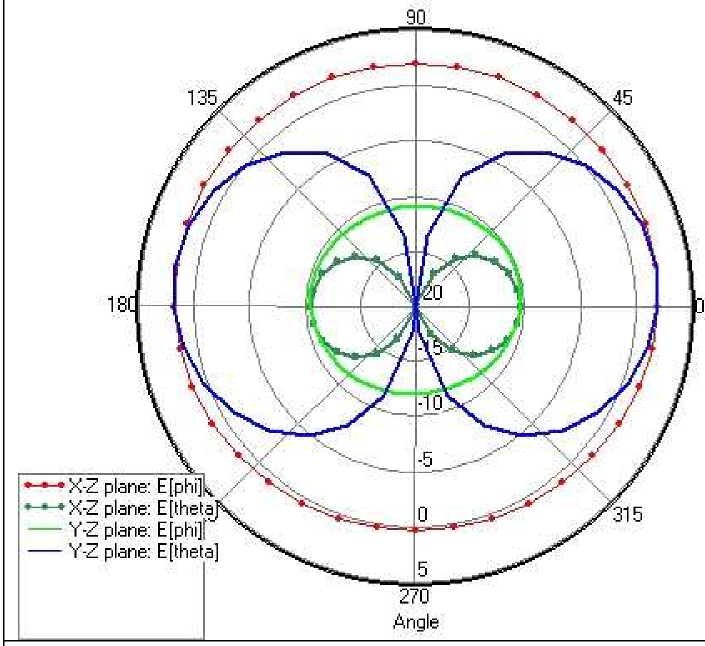
SET-UP 3: Electric field over the antenna and PCB Ground plane at the resonant frequency of 1.0 GHz. Arrows show the main direction of electromagnetic field over the PCB. This gives a longer length than the SET-UP 2 and therefore lower resonance frequency. 	**SET-UP 3:** Electric field over the antenna and PCB Ground plane at the resonant frequency of 1.32 GHz. Arrows show the main direction of electromagnetic field over the PCB. This gives a longer length than the SET-UP 2 and therefore lower resonance frequency. 
SET-UP 4: Electric field over the antenna and PCB Ground plane at the resonant frequency of 1.2 GHz. This gives higher field strength at the antenna and the ground close to the antenna. Less usage of the PCB Ground plane will give a smaller effective antenna area and therefore lower gain but the radiation will be more omni-directional. The main field and therefore the antenna effective area is enclosed within the ring. 	

Table 3: Radiation result from one antenna placed on different PCB's

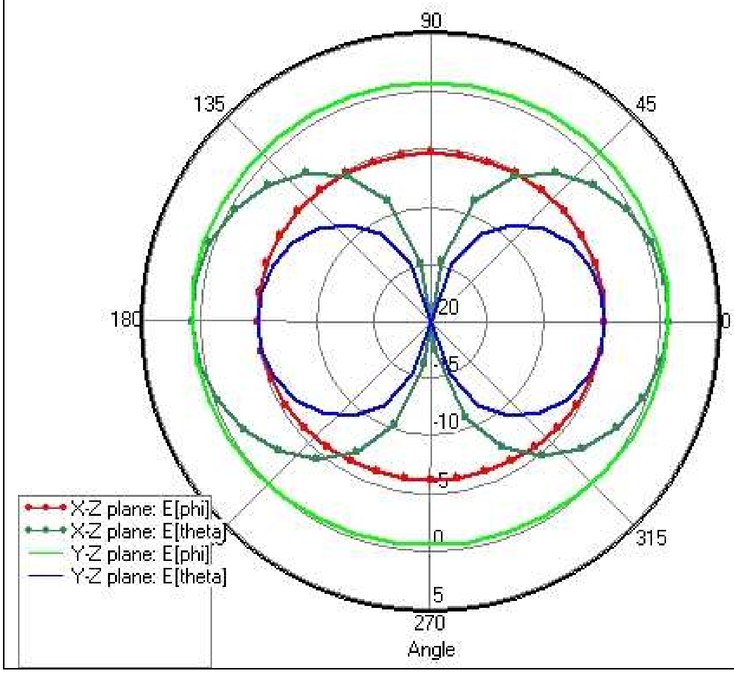
SET-UP 2:

The radiation characteristic for the SET-UP 2 at the resonant frequency of 1.0 GHz. The radiating system is omni directional in the X-Z plane with max gain of 2 dBi. This gain is similar as a dipole and is due to the fact that the longest distance is about 130 mm of the radiating system. The cross polarization is low.



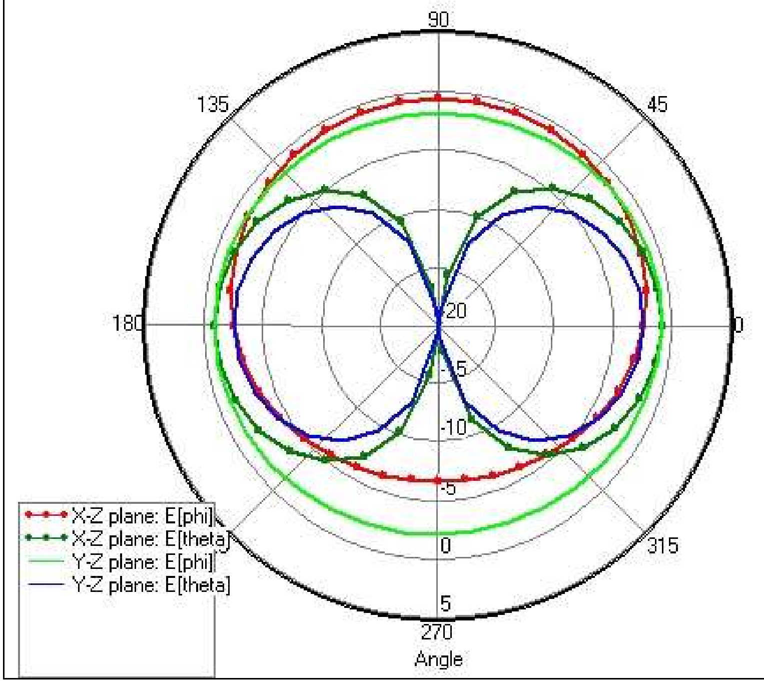
SET-UP 3:

The radiation characteristic for the SET-UP 3 at the resonant frequency of 1.0 GHz. The max gain is 0.5 dBi. The cross polarization is higher since the antenna and PCB is located with 90 degrees angle. The dominant gain is in Y-Z plane showing that the PCB contribute more to radiation than the antenna itself.



SET-UP 4:

The radiation characteristic for the SET-UP 4 at the resonant frequency of 1.2 GHz. The max gain is -0.5 dBi. Both X-Z and Y-Z plane have similar radiation characteristics. This radiating system has lower max but a mixed polarization and radiating direction. This is due to the position of antenna and shape of ground plane.



3. EMC considerations when using embedded antennas.

Another challenge when embedding antennas is to keep the noise level in the radio frequency range very low. The EMC compliance level is measured at a remote distance and the levels are set in such way that other units at 3 m distance not shall be disturbed. When using an embedded antenna it can be self disturbed by internal noise since the antenna is very close to the electronics including CPU and other digital part using an internal clock and often high speed busses. A receiver with sensitivity of -100 dBm corresponds to a power level of 0.1 pW and a voltage of 2 uV (50 ohms system). Even though the receiver uses a frequency of several hundreds of megahertz multiple frequencies of a clock will create disturbing signal levels unless it is very good shielded and bounded into the PCB. The 37th harmonic of 25 MHz is located at 925 MHz and is in the GSM down link band (receiving at mobile terminal). Also other sources can cause disturbing levels easily and can cause a bad working wireless system regardless of the antenna performance itself. Figure 1 shows how the noise from CPU is received by the antenna. It shows also a simple test to verify if bad reception is caused by noise by using an antenna on cable and very the distance to PCB. Figure 2 shows a scanner equipment and a scanning plot and figure 3 shows a spectrum of a scanning with peaks at 925, 936, 950 MHz, all within the GSM receiving spectrum of an mobile device.

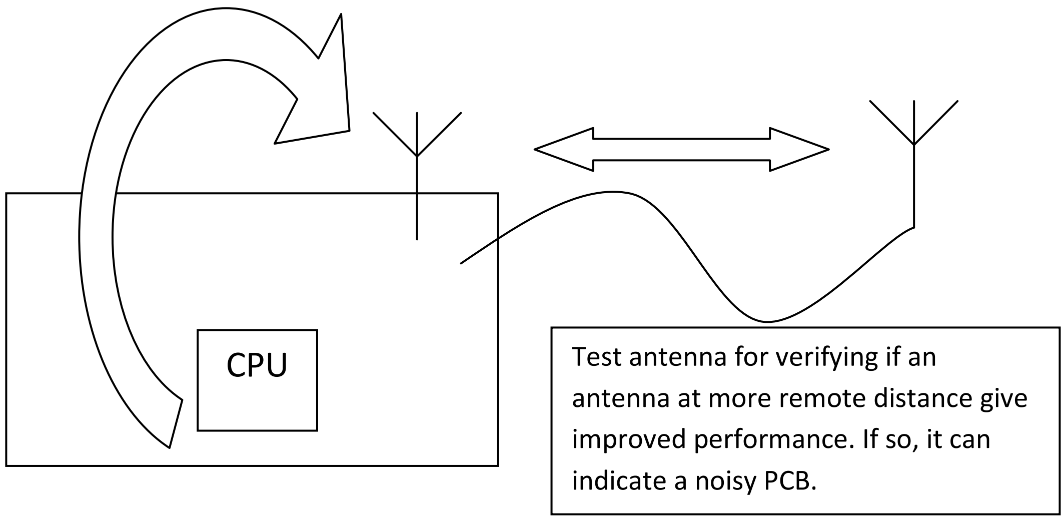


Figure 1: Measurement set-up for verifying the level of disturbing signals from PCB

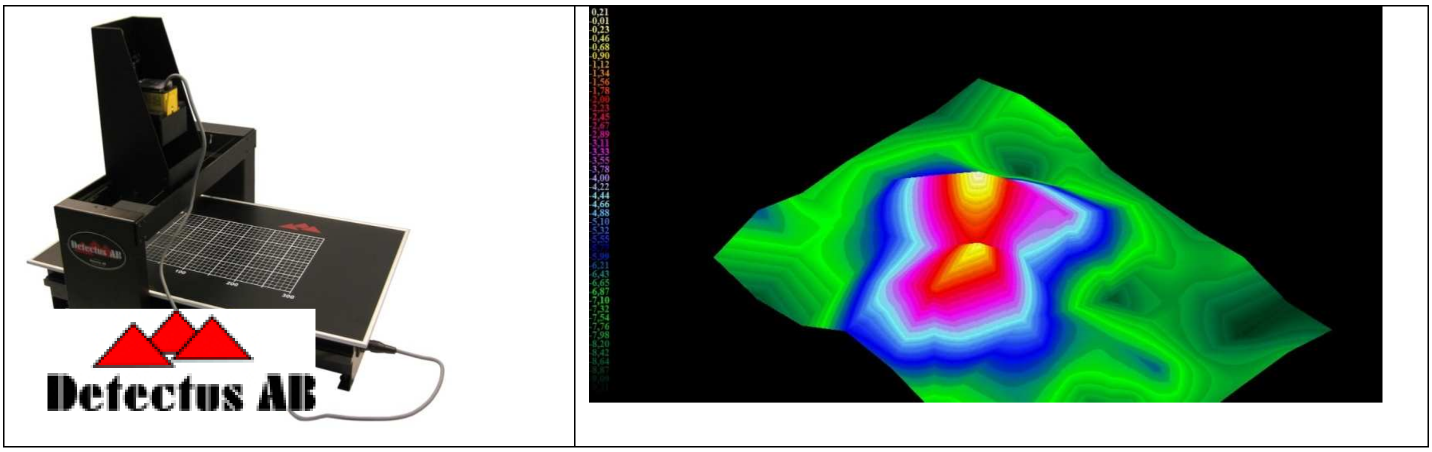


Figure 2: Scanner for locate noisy parts on PCB.

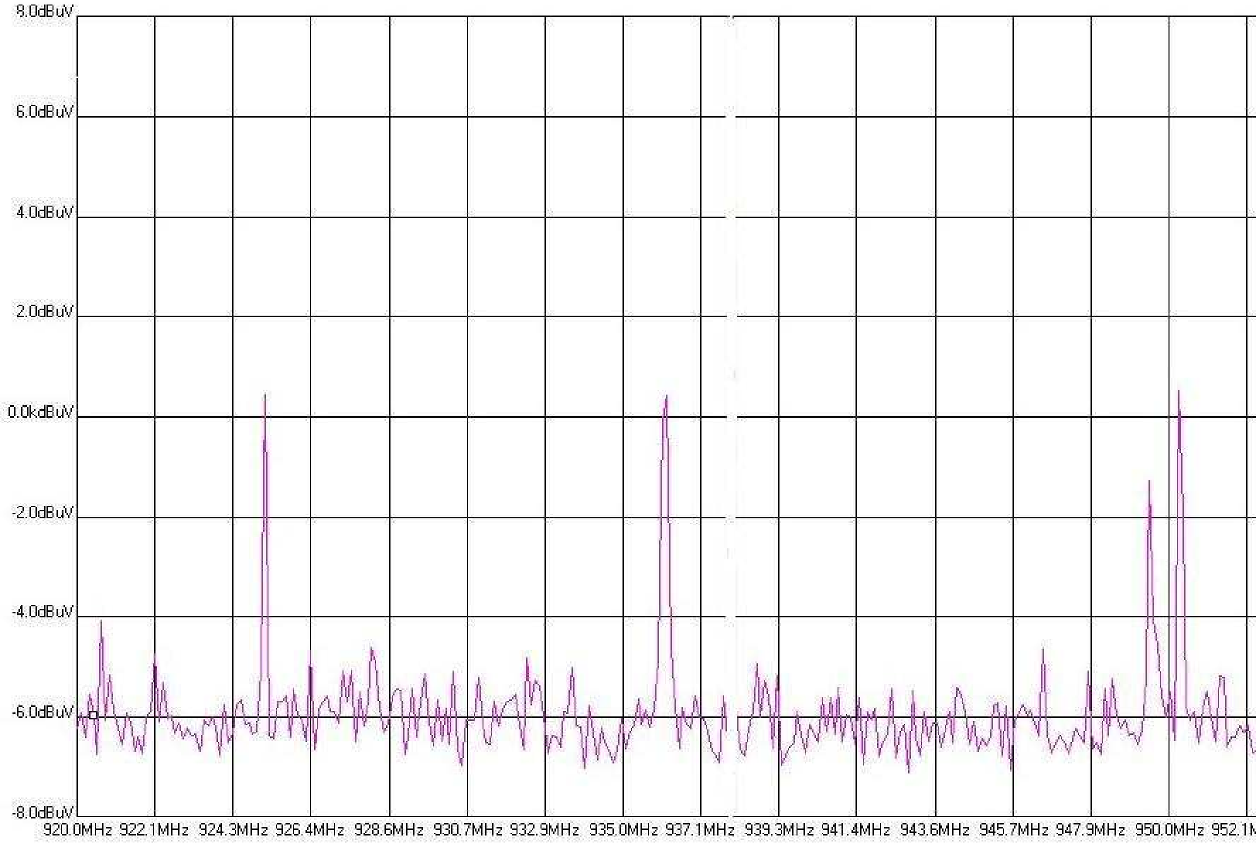


Figure 3: Frequency spectrum of a scanning of PCB.

4. Discussion

This paper show basic behavior of one antenna placed on different PCB's. The result is simulated in XFDTD but is also verified during working practice at ProAnt AB. The simulations are done with ideal material so difference in frequency and levels will occur in practice however the aim of this paper is to show some key aspect when implementing antennas for embedded applications. The antenna performance can be optimized and secured by doing some simple test when starting product development. After the rough test at start the antenna needs to be optimized and tuned at a later stage when the mechanics is finished.

This paper shows also a measurement of disturbing signals by using a scanner and scanning the PCB. Also this is important to ensure a good product. The signal level of the scanning will varies depending of distance from the probe to the PCB. This is a tool of detecting from what spot noise is emitted from to help improving the PCB layout.

5. References

[1] : Jan Eriksson: Detectus scanner software v2.7. www.detectus.se